DOCUMENT RESUME

ED 451 987 RC 022 923

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TITLE	Two Canadian Approaches to Teaching Biology, Chemistry, Mathematics and Physics to Senior High School Students in Virtual Classes.
PUB DATE	1999-07-00
NOTE	15p.; Paper presented at the Australasian Science Education Research Association (New Zealand, July 1999).
PUB TYPE	Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	Computer Uses in Education; *Distance Education; *Educational Cooperation; Foreign Countries; Geographic Isolation; High Schools; Information Technology; *Internet; *Rural Education; Science Education; Shared Resources and Services; *Teaching Methods
IDENTIFIERS	*Intranets; Newfoundland; Technology Integration; *Web Based Instruction

ABSTRACT

The successful integration of information technologies in the teaching of biology and other sciences is in part dependent on the transition from closed to open teaching and learning environments. This paper outlines the transition from a closed model of schooling in rural Newfoundland and Labrador to the beginnings of an open model. Seniors in a rural Newfoundland high school participated in a study evaluating the use of Internet resources to enhance biology education. Three biology topics were taught using three different methods of instruction: traditional, in which students were taught face to face by the teacher from the textbook; cooperative, in which students worked together using text and Internet sources selected by the teacher; and Internet, in which students worked individually and used Internet sources. Results indicate that Internet resources have the potential to enhance student learning. This approach is referred to as a "closed" model, because the school is autonomous and has its own students, teachers, and community. The installation of a digital intranet linking nine schools in the Vista school district (Newfoundland) created an "open" model of education in that classes in different schools share teaching, learning, and resources. This open model is grounded in the application of information technology and the construction of virtual classes. Factors to consider in developing a pedagogy appropriate for the open model are discussed. (TD)

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Two Canadian Approaches to Teaching Biology, Chemistry, Mathematics and Physics to Senior High School Students in Virtual Classes

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ED 451 987

Prepared for the *Australasian Science Education Research Association*
July 1999

An earlier version of this paper was presented to the TeleLearning Network of Centres of Excellence, Vancouver, Canada, November 1998

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RC 022923

Abstract

This paper outlines two approaches to teaching Biology, Chemistry, Mathematics and Physics to senior students in rural Canadian high schools. The first approach outlines teaching and learning within a closed electronic teaching and learning structure, while the second approach examines the teaching of these science subjects within the more open environment of a digital intranet. It is argued in this paper, on the basis of current research in Atlantic Canada, that the successful integration of information and communication technologies in the teaching of Biology, Chemistry, Mathematics and Physics is in part dependent on the transition from closed to open teaching and learning environments. In each approach to the teaching and learning of science in virtual classes, management and policy issues at the school level are considered. The paper will conclude with a consideration of the implications of teleteaching and telelearning using virtual classes for the professional education of science teachers, drawing on both Canadian and New Zealand research.

Biographical Note

Ken Stevens is a Professor of Education at Memorial University of Newfoundland where he holds the Chair of TeleLearning and Rural Education. His previous appointments were at Victoria University of Wellington in New Zealand and at James Cook University in Australia.

Two Canadian Approaches to Teaching Biology, Chemistry, Mathematics and Physics to Senior High School Students in Virtual Classes

TeleLearning is a new term in the educational lexicon. It involves educators in a re-conceptualization of teaching, learning, the management of schools and, ultimately, educational policy. Recently telelearning has been called the future of distance learning (Collis, 1996). The introduction of telelearning in a school, school district or province involves major changes in teaching, learning and the organization of education, particularly at the local level. At the present time, many schools are in transition between traditional and virtual ways of organizing teaching and learning as they seek to integrate information and communication technologies in classrooms.

This paper outlines the transition from traditional (face to face) to virtual teaching and learning environments in selected Newfoundland and Labrador schools. It is argued, on the basis of research in science classes in Newfoundland and Labrador in 1997 and 1998, that the introduction of telelearning in schools and at faculty level involves a shift from a closed to an open model of teaching and learning.

The Context of the Study

Newfoundland and Labrador is characterized by geographic isolation, rural lifestyles, a distinctive history and culture and high unemployment. In the 1997-98 school year, there are 391 schools operating in the province of which 260, or 66%, are located in rural communities. Thirty one percent of schools in the province are designated "small rural schools" (N=122) and 75 of these have fewer than 100 students. Furthermore, 70 of these small rural schools are all-grade (K –12) which means that they must offer a senior high school program.

The recent re-organization of Primary, Elementary and Secondary education in Newfoundland and Labrador into ten school districts provides an opportunity to develop the first digital Intranet in the province. The Vista School District contains 18 schools ranging in student enrolment from 650 down to 40, including Clarenville High School. The region in which the Vista School District is located extends from Bonavista in the north, (the place where John Cabot landed in North America in 1497) to the Burin Peninsula in the South. It is a large geographic area covering about 7000 square kilometres. The region has a population of about 35,000 people and an economy supported by a diverse infrastructure including fishing, forestry, farming, mining, aquaculture and tourism. The Vista School District was formed in 1996 and became a legal entity in January 1997. There are 5165 students enrolled in 18 schools in the district who are taught by 366 teachers. The Vista School District is approximately two hours by road from the capital city, St Johns, which is the location of Memorial University of Newfoundland.

Clarenville High School is one of the larger schools in rural eastern Newfoundland and was chosen in 1996 as the telelearning test site school. Its enrollment in 1998-99 is 480 students. (See: http://www.k12.nf.ca/clarenville-high/).

Closed and Open Schools

Schools as we have known them are autonomous institutions with their own teachers, their own students and their own cultures. Traditionally schools have been established to serve geographically defined communities and, in rural areas, this relationship is a particularly close one. Schools in each community to a considerable extent duplicate what schools are doing in other communities with students being taught by teachers assigned to them to teach face to face as whole classes, small groups and, in some cases, individually. There is nothing remarkable about this model of the school and it is an accepted part of the global educational landscape. Perhaps the most remarkable thing about this model of the school is that it remains largely unchallenged.

The above model, for the purposes of this paper, will be referred to as a "closed model of the school." In this model, the school is considered to be closed if it is autonomous and has its own students, teachers and community. It is, in this way, considered to be a small, enclosed teaching and learning environment.

The open model challenges the closed model of the school. The open model is based on schools academically and administratively integrating with one another for at least part of a school day. Information and communication technologies facilitate the linking of classes in schools to share teaching, learning and resources. In Newfoundland and Labrador virtual classes have been a feature of the province's education system since 1988 when audiographic technology was installed to establish an analog learning network. The transition from an analog network to a digital network is a critical part of this research.

The open model challenges the closed model of the school by questioning the need for appointing all teachers to schools, rather than, in appropriate cases, some teachers being appointed to networks of schools. It questions the appropriateness of learners engaging solely with their peers within their own, physical classrooms and, it questions the very notion of a school itself. The open model of the school is grounded in the application of information and communication technologies to teaching and learning and the construction and deconstruction of virtual classes.

In the tension between closed and open classes teachers are increasingly engaged in a search for appropriate pedagogy. A pedagogy of telelearning will facilitate on site and on line teaching and learning as well as the administration of open classes.

This paper outlines the path between a closed model of the school in rural Newfoundland and Labrador to the beginnings of an open model. It is based on teaching and learning in selected science classes in rural parts of the province.

Five Phases in the Move from Closed to Open Classes in Newfoundland and Labrador

The introduction of computers and the Internet to schools in Newfoundland and Labrador took place gradually, in closed teaching and learning environments which gradually became more open. At the beginning of the TL-NCE4.3 study, Clarenville High School was at phase four.

Phase One: Computers as a Subject of Study

In the late 1980's and early 1990's computer technology was introduced to classes with little of no formal training of the teachers who used it. Teachers frequently learnt how computers worked though their own study of them with little help from outside sources. In this phase of telelearning, computers were a subject of study. Some teachers studied computers to find out how they worked and how they could be programmed while, to most of the profession, this technology was not considered to be directly relevant to classroom life. There was little thought given to the integration of computers to teaching and learning.

Phase Two: Computers and Course Re-Development

In the early 1990's the Lighthouse Schools Project (computer networks in schools) was introduced and some teachers began to realize the potential of computers for both teaching and student learning. Local Area Networks (LANs) were introduced in Newfoundland and Labrador. While there was awareness of the Internet it was not used in Newfoundland and Labrador schools at this time. However, computers were used to capture data for science experiments using Vernier hardware and software. Students were shown how to use word processing, spreadsheets and graphing software in completing their assignments and some entire courses were re-developed around such uses of computer technology.

Phase Three: Internet Access

In 1993 the introduction of Internet access to selected teachers in Newfoundland and Labrador led to the formation of STEM~Net, the provincial arm of SchoolNet, based at Memorial University of Newfoundland. Within a two year period more than five thousand teachers were provided with access to the Internet through STEM~Net. Training sessions were provided in the use of E-mail and the development of web-pages (HTML). Subject area web pages began to appear, initially designed for the assistance of teachers rather than for students. Soon, however, some teachers began to ask for student access to the Internet and from this, the STELLAR Schools project was initiated as a partnership between STEM~Net and Cable Atlantic. STELLAR schools projects facilitated the development of student Internet resources.

Phase Four: Integrating Technologies

By 1996-97 Newfoundland and Labrador schools had a high level of connectivity, per capita. The development of web-pages by students in schools was accompanied by the introduction of other areas of school life to the web such as homework exercises, answers to questions, school policies and schedules of events. Early attempts to bring information technologies into teaching and learning were in the form of text on line and links to other sites (mostly Universities). Internet resources and CD-ROMs became increasingly available to both teachers and learners, facilitating interaction between dispersed sites.

Five: The Digital Intranet

The Vista School District Digital Intranet project in 1998 is an attempt to determine how to deliver real time educational instruction across dispersed sites, all of which are located in rural Newfoundland. Lead teachers in Biology, Chemistry, Mathematics and Physics are at present piloting the delivery of Advanced Placement courses in these subjects.

The Closed Model of Teaching Science Using Information Technologies - Biology at Clarenville High School

Biology was chosen for study at Clarenville High School because of the breadth it provided for research. Physics and Chemistry were not considered to be as appropriate because of the much narrower and more academic stream of students who enrolled in these courses. Biology attracted a wider range of students within the school than either Chemistry or Physics. sAll the Biology courses in this school are taught by one teacher who has advanced computer skills and who became a partner in the experiments in this area of the curriculum.

Students taking Biology 2201 were involved in a study to evaluate the use of Internet resources to enhance their biology education. Three Biology 2201 classes were selected to take part in the study. The study involved three topics taken from Unit IV - Homeostasis. Each of the three classes was taught using three different methods of instruction defined as:

1. *Traditional* (lecture, assignments, videos, etc.). In the traditional group students were taught face to face by the teacher from the textbook. This was the way in which students were used to being taught so this created no change for either teacher or students. The students in this group did not experience any changes in their mode of instruction.

2. *Cooperative* (students being much more responsible for their own learning and sharing what they learn with their peers). In the cooperative group students were

able to work together on learning biology, using text sources as well as a website that enabled them to visit appropriate areas of the Internet that were selected by their teacher. These students worked with a lot less direct teaching from their Biology teacher.

3. *Internet* (students gathering information from Internet resources to complete the intended learning outcomes). In this group students were to work individually and to use Internet sources to complete their Biology units of study. Internet students were able to work with more freedom than those being taught face to face and were therefore dependent to some extent on personal discipline as well as facility in using information technologies.

Each topic of study involved nine periods (57 minutes) of instructional time and one period for evaluation (pre-test and post-test) over a 14 day school cycle. Upon completing each cycle of instruction in a given methodology, each study group began the next topic using a different instructional practice. By the end of the study each class group had been exposed to all three instructional methodologies. The topics chosen were considered by the instructor to be of equal difficulty. Pre-test and post-test data was collected so that a quantitative comparison could be made. Upon completion of the study, students completed a qualitative evaluation which asked them to provide information about their preferences for each instructional method. All students had the same prescribed text (Schraer. *Biology: The Study of Life*). The tables below indicate the pre-test and post-test class averages and standard deviations. Each pre-test and post-test (Tables 2, 3 and 4) contained 25 multiple choice questions, each question had 4 possible answers. Data in the tables are raw scores and are not corrected for guessing.

Table 1, below, gives information that might be useful in comparing the three Biology 2201 classes that took part in the study. The letters "B", "C", and "D" only refer to the slot within the school timetable and have no other significance. The school timetable runs over a period of 14 school days. Each 14 day cycle has 10 periods (57 min. each) of biology instruction. "Number" refers to the number of students in each of the Biology 2201 classes. "Class Average Prior to Study" refers to the class average mark based on all work prior to the start of the study. This mark represents the average of 27 pieces of evaluation in each of the three classes. Each quiz, lab report, assignment, etc. was the same for all students and all three classes and was collected throughout the year of instruction prior to the study period. "Class Average Unit Examination" refers to the class average on the unit examination completed at the end of the study. "Standard Deviation Unit Exam" is the standard deviation for each class on the unit examination. The unit examination covered five (5) sections (Chapters 12 - 16) of work. Only three (3) sections (Chapters 14 - 16) were part of the study.

Table 2, below, shows the results of the first round in the study. This was a study of the nervous system (Chapter 14). Each class was taught using a different teaching strategy as indicated in the table. Students received 9 periods of instruction during a 14 day cycle. Period 10 of the cycle was used for evaluation.

Table 3, below, indicates the results of the second round (Chapter 15). The classes remained the same in terms of the students but the teaching strategy was changed as indicated under "Method of Instruction." Again, students received 9 periods of exposure to the teaching strategy in the 14 day cycle. The 10th period was used for evaluation. Please notice that the results of the pretest are not yet available. A pretest was given but has not yet been scored.

Table 4 below indicates the results of the third round in the study (Chapter 16). Again the students remained the same but the teaching strategy was changed. Students of Class B and D received nine (9) hours of instruction and 1 hour for evaluation. Class C (33 students) received 6 periods using computer, three (3) periods using traditional instruction, and 1 period for evaluation. With 33 students in the Class C, it became necessary to abandon the study after 6 periods (rather than the intended 9 periods). This was due to several factors including: students complaining about overcrowded conditions, the room being too hot and uncomfortable, the non-availability of a printer and only 11 computers were at the time being in service.

Table 1 (General Information for Comparison)

Class	Number of Students	Class Average Prior to Study	Class Average Unit examination	Standard Deviation Unit Examination
B	21	61.7	46.8	12.7
C	33	68.5	60.6	17.5
D	29	68.4	58.2	14.4

Table 2 (Chapter 14)

Class	Method of Instruction	Pretest Average Mark	Pretest Standard Deviation	Post Test Average Mark	Post Test Standard Deviation
B	Traditional	25.0	8.2	54.9	14.6
C	Cooperative	30.6	9.5	59.9	23.3
D	Computer	25.9	10.0	59.4	21.8

Table 3 (Chapter 15)

Class	Method of Instruction	Pretest Average Mark	Pretest Standard Deviation	Post Test Average Mark	Post Test Standard Deviation
B	Computer	N/A	N/A	41.6	21.3
C	Traditional	N/A	N/A	63.6	22.8
D	Cooperative	N/A	N/A	64.9	18.6

Table 4 (Chapter 16)

Class	Method of Instruction	Pretest Average Mark	Pretest Standard Deviation	Post Test Average Mark	Post Test Standard Deviation
B	Cooperative	27.5	11.0	67.4	8.2
C	Computer (see note)	31.8	7.7	66.4	19.9
D	Traditional	29.0	13.2	71.7	11.1

On completion of the study students completed a qualitative evaluation survey intended to gather data regarding their experience with each teaching method. Each student was asked to explain in their own words, what "traditional", "cooperative", and "computer" teaching strategies meant to them. The student also wrote a brief description of what they believed represented the best teaching method - how they would like to be taught in future.

Traditional:

"The teacher told us what we needed to know and gave us notes"
"The teacher stands in front of the class writing out notes...it's basically boring"
"I feel this type of learning was good, but it is the most boring"

Cooperative:

"I think this is a very effective way of learning"
"Students look for information themselves and help each other. The teacher is just there for guidance"
"The teacher gives us a concept or question – we form into groups and do the research"

Internet:

"Very hard to use but if used right it can help a great deal"
"This was the greatest method but people got off the topic"
"Most students spend their time on topics completely unrelated to the subject and the teacher doesn't know"

The feedback indicated that students would prefer to be taught using a combination of strategies. All three groups indicated that reliance on a single instructional strategy was not to their benefit. Students also indicated that the 9 hour period was inadequate. It was suggested that students first receive training in the use of the technology (to become familiar with the software and hardware) before they could make efficient use of internet resources. Most students reported some degree of frustration mostly associated with their lack of computer skills and their inability to focus on the task assigned.

In future it will be necessary to provide time for students to first learn how to make efficient use of the technology before beginning any research project. It appears however, that use of internet resources has the potential to enhance student learning in the subject of biology.

The Open Model of Teaching Science: The Vista School District Digital Intranet

There are ten school districts in Newfoundland and Labrador of which the Vista School district is number eight. The electronic linking of nine sites within this district to collaborate in the teaching of Advanced Placement Biology, Chemistry, Mathematics and Physics has created a series of virtual classes in this area of rural Newfoundland. Classes began in September 1998 and an initial report (Stevens, 1998) has been completed.

The introduction of the Vista School District Digital Intranet represents two dimensions of change: (a) curriculum and technology and (b) the re-organization of classes within an Intranet.

(a) Curriculum and Technology: The 4 x 4 Model of Integrating Information Technologies into the Curriculum

The development of Advanced Placement Web-based courses in Biology, Chemistry, Mathematics and Physics took place within a development team in each subject area. A lead science teacher in each discipline was paired with a recent graduate in Biology, Chemistry, Mathematics and Physics respectively who possessed advanced computer skills including web page design, Java and HTML. The lead teacher and the graduate assistant were, ideally, to have been assisted by a Faculty of Education specialist in each curriculum area together with a scientist from an appropriate area of the Faculty of Science at Memorial University of Newfoundland. It is anticipated that there will be Faculty of Education and Faculty of Science input in all four areas in future. The extent to which each Web-based course was developed by a team of four people varied. Most of the development was through interaction between the lead teacher and the recent graduate with reference, as appropriate, to two professors (Science Education and Science).

This model provided a measure of interaction between schools, graduate students and the Faculties of Education and Science of Memorial University of Newfoundland. To provide a connection between the high school and Memorial University, faculty members were asked to take part in providing resources, quality control evaluation and suggestions for improvement. Although at times professors had different opinions as to the most appropriate approach to the design of the courses, the 4 x 4 model enabled the four courses to be developed in time for the current school year.

Several issues had to be considered in the development of the four AP courses:

1. *What hardware and software resources would be required to deliver instruction of an AP course to high school students in rural schools?*

Minimum specifications were adopted for computer hardware and network connectivity. All schools involved in the project had satellite dishes installed. Software had to be identified and evaluated. Software was required for both the development of the resources, and the delivery of instruction.

Software for development of the AP resources:

Front Page 98 was selected as the software package. Additional software was used for development of images, animated gifs, etc. These included Snagit32, Gif Construction Set, Real Video, and similar packages.

Software for student management and delivery of instruction:

Many software packages were evaluated and finallyWebCT was selected. This package enabled the instructor to track student progress, it contained online testing and evaluation, private email, a calendar feature, public bulletin board for use by both instructor and student, a link to lessons, chat rooms for communication between teacher and student, and more.

For real time instruction Meeting Point and Microsoft NetMeeting were selected. This combination of software enabled a teacher to present real-time interactive instruction to multiple sites.

2. *Students require training in the use of the hardware and software.*

An orientation session was provided to students in June of the year prior to implementation. Visits by instructors have also been carried out where required. Students are learning how to communicate with each other and with their instructor.

(b) The Re-organization of Classes In an Intranet

1. *Problems associated with the delivery of the lab component for the three science courses.*

Problems of supervision and safety have had to be considered. This remains an issue that has not been finally resolved. The use of online video files and CD-ROMs are being explored.

2. *The nature of the high school students taking the AP courses.*

The question how students would work in a completely independent learning environment has been prominent in the minds of researchers from the outset of each AP course. There is no teacher present on site and students are not normally used to being alone and largely unsupervised. Will they cope successfully with such freedom and responsibility? It is too early to determine the answer to this question.

3. *Synchronous and Asynchronous: Establishing a common schedule (time-table) in all schools within the district.*

It was recognized early that a common schedule must be adopted throughout the district to allow students to be able to interact with their instructors. The initial plan was to allow for 5 online sessions and 5 offline sessions. This schedule was not followed in all schools. Online sessions are scheduled in the morning when network traffic is at its lowest point. Off line sessions are scheduled in the afternoon. Some schools chose not to be coordinated with the AP schedule for various valid reasons. As a result the instructor might be teaching another subject when the AP student would be in class. Students in different schools therefore have differing access to their AP Instructors. It is anticipated that in future there will be both asynchronous as well as synchronous teaching and learning within the Intranet, but at the present time it is not possible to provide other than synchronous access.

4. *The problem of student evaluation.*

The delivery of evaluation instruments is still being considered, but the researchers' preference is for electronic delivery. Both traditional paper/pencil and online testing are being evaluated. Student preference at present is for paper/pencil type tests.

Conclusion: The Management of Isolation in Newfoundland and Labrador

The Vista School District Digital Intranet is a prototype for the other nine school districts in the province. There are a number of problems to be resolved during the first year and the prototype is being monitored regularly and a full evaluation will be completed by June 1999. This model of delivering education and the technology that has been installed are currently being evaluated and from this, the provincial government will be in a position to consider its implications for other school districts in Newfoundland and Labrador.

The move from a closed to an open environment in the teaching and learning of science is based upon a transition from an analog to a digital environment. Newfoundland and Labrador has a high rate of use of satellite dishes per capita and there are many schools in

this province with LANs. As a province Newfoundland and Labrador provides excellent opportunities for the development of these technologies.

There are a number of implications for both teaching and learning in this development that have been noted by observers since the recent inception of the Digital Intranet:

Implications for Teaching:

1. Teachers of the four science disciplines are appointed to closed learning environments from which they teach in open classes for at least part of a school day. In each case they are part of an established, physical school as well as a virtual one.
2. Teachers' work in each web-based science course is open to the scrutiny of other members of the profession on the Internet.
3. Teachers assigned to teach web-based AP courses have achieved a new prominence in the profession in Newfoundland and Labrador.

Implications for Learning:

1. The instructors in each of the four science subjects are all male;
2. Only science subjects are currently provided in the Intranet. Some people have already expressed disappointment that a wider range of options is not yet available.
3. Only Advanced Placement subjects are being currently taught, thereby limiting the range of student participants.

The Vista School District Digital Intranet is an attempt to use information technologies to provide geographically-isolated students with increased educational and vocational opportunities. This is part of a broader pan-Canadian initiative to prepare people in this country for the Information Age (Information Highway Advisory Council, 1995,1997). It is rare to find high school students in small and remote communities anywhere in the world who are provided with instruction in university-level studies. In Iceland (Stefansdottir, 1993), New Zealand (Stevens, 1995a, 1995b) and Finland (Tella, 1995) there are moves to provide alternative models for the delivery of education to rural students. However, the Vista School District Digital Intranet provides educators in other parts of the world with the beginnings of a new model of rural education.

The Digital Intranet challenges the closed model of the school and manages geographic isolation in a new way. There will, hopefully, be future opportunities to take this development to other areas of the curriculum, to other school districts and to other than AP students in schools. Through the application and coordination of a range of technologies, some Advanced Placement students in Newfoundland and Labrador have, in the current school year, been able to move from closed to open learning environments. The broader educational and sociological implications of this development have yet to be considered.

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